INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/00875

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H01F 27/34
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EDOC, WPIL, JAPIO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 1438610 A (BBC BROWN BOVERI & COMPANY LIMITED), 9 June 1976 (09.06.76) --	1
A	US 4109098 A (M.G. OLSSON ET AL), 22 August 1978 (22.08.78) -- --------	1

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" erlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 Sept 1997	03 -10- 1997
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Magnus Westöö Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT
Information on patent family members

01/09/97

International application No.
PCT/SE 97/00875

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 1438610 A	09/06/76	AT 335541 B	10/03/77
		BE 817268 A	04/11/74
		BR 7405500 A	03/03/76
		CH 560448 A	27/03/75
		DE 2341983 A	23/01/75
		DE 7330301 U	28/08/75
		FR 2236252 A,B	31/01/75
		JP 50036986 A	07/04/75
US 4109098 A	22/08/78	AR 211382 A	15/12/77
		AU 7707175 A	08/07/76
		BE 825068 A	15/05/75
		BR 7500229 A	04/11/75
		CA 1038052 A	05/09/78
		CH 587545 A	13/05/77
		DE 2501811 A	14/08/75
		DK 32675 A	29/09/75
		FR 2260173 A,B	29/08/75
		GB 1493163 A	23/11/77
		JP 50109479 A	28/08/75
		NL 7501168 A	04/08/75
		SE 384420 B,C	03/05/76
		SE 7401244 A	01/08/75

08/973210

PCT/SE97/00875

PATENT COOPERATION TREATY

5630

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

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Crystal Plaza 2
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in its capacity as elected Office

Date of mailing (day/month/year) 31 December 1997 (31.12.97)	
International application No. PCT/SE97/00875	**Applicant's or agent's file reference** KN 8137
International filing date (day/month/year) 27 May 1997 (27.05.97)	**Priority date** (day/month/year) 29 May 1996 (29.05.96)
Applicant LEIJON, Mats	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

02 December 1997 (02.12.97)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was
[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Aino Metcalfe Telephone No.: (41-22) 338.83.38

5[illegible]0 08/97[illegible], 270 19

PATENT COOPERATION TREATY

REC'D 12 OCT 1998
WIPO PCT

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference KN 8137 WO	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/SE97/00875	International filing date *(day/month/year)* 27.05.1997	Priority date *(day/month/year)* 29.05.1996
International Patent Classification (IPC) or national classification and IPC_6 H 01 F 27/34		
Applicant Asea Brown Boveri AB et al		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 3 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of ______ sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand 02.12.1997	Date of completion of this report 06.10.1998
Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Telex 17978 PATOREG-S Facsimile No. 08-667 72 88	Authorized officer Magnus Westöö Telephone No. 08-782 25 00

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/SE97/00875

I. Basis of the report

1. This report has been drawn on the basis of *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.)*:

☒ the international application as originally filed.

☐ the description, pages ______, as originally filed,
pages ______, filed with the demand,
pages ______, filed with the letter of ______,
pages ______, filed with the letter of ______.

☐ the claims, Nos. ______, as originally filed,
Nos. ______, as amended under Article 19,
Nos. ______, filed with the demand,
Nos. ______, filed with the letter of ______,
Nos. ______, filed with the letter of ______.

☐ the drawings, ~~sheets~~/fig ______, as originally filed,
~~sheets~~/fig ______, filed with the demand
~~sheets~~/fig ______, filed with the letter of ______,
~~sheets~~/fig ______, filed with the letter of ______.

2. The amendments have resulted in the cancellation of:

☐ the description, pages ______

☐ the claims, Nos. ______

☐ the drawings, ~~sheets~~/fig ______

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the supplemental Box (Rule 70.2(c)).

4. Additional observations, if necessary:

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/SE97/00875

V. Resoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-25	YES
	Claims		NO
Inventive step (IS)	Claims	1-25	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-25	YES
	Claims		NO

2. Citations and explanations

D1: GB 1438610 A
D2: US 4109098 A

The invention relates to a power transformer/reactor comprising at least one winding. The invention is characterized in that around each conductor there are arranged layers with semiconducting properties, as defined in the characterizing part of claim 1. The invention also relates to the cooling of a power transformer/reactor, a method for electric field control in a power transformer/reactor and a method in production of a power transformer/reactor.

The document D1 discloses a resin-insulated high-voltage conductor, having semiconductive foam resin between conductor and insulation.

The document D2 discloses a high voltage cable, having on its conductor core an inner layer of semiconducting material. An insulation layer encompasses this semiconducting layer and is in turn encompassed by an outer semiconducting layer.

The documents D1 and D2 show the state of the art technology but do not anticipate the claimed invention. The requirements of novelty and inventive step are therefore considered to be fulfilled.

The industrial applicability of the invention is obvious.

8137

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REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No. SE97/00875

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* KN 8137

28 NOV 1997

Box No. I TITLE OF INVENTION

TRANSFORMER/REACTOR

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (i.e. country) of residence if no State of residence is indicated below.)*

Asea Brown Boveri AB
S-721 83 VÄSTERÅS
Sweden

☐ This person is also inventor.

Telephone No. +46 21 32 50 00

Facsimile No. +46 21 13 41 12

Teleprinter No.

State *(i.e. country)* of nationality: Sweden

State *(i.e. country)* of residence: Sweden

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (i.e. country) of residence if no State of residence is indicated below.)*

LEIJON, Mats
Hyvlargatan 5
S-723 35 VÄSTERÅS
Sweden

This person is:
☐ applicant only
☒ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: Sweden

State *(i.e. country)* of residence: Sweden

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

DAHLSTRAND, Björn; JENKLER, Malte

Asea Brown Boveri AB
Patent, Stockholm Office
S-120 86 STOCKHOLM
Sweden

Telephone No. +46 8 658 81 30

Facsimile No. +46 8 644 35 72

Teleprinter No.

☐ Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Sheet No. ..2.....

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

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[X] EA Eurasian Patent: AM Armenia, AZ Azerbaijan, BY Belarus, KG Kyrgyzstan, KZ Kazakstan, MD Republic of Moldova, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT

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- [X] AM Armenia
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- [X] CN China
- [X] CU Cuba
- [X] CZ Czech Republic and utility model
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- [X] HU Hungary
- [X] IL Israel
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- [X] JP Japan
- [X] KE Kenya
- [X] KG Kyrgyzstan
- [X] KP Democratic People's Republic of Korea
- [X] KR Republic of Korea
- [X] KZ Kazakstan
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- [X] LR Liberia
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- [X] LU Luxembourg
- [X] LV Latvia
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- [X] MG Madagascar
- [X] MK The former Yugoslav Republic of Macedonia
- [X] MN Mongolia
- [X] MW Malawi
- [X] MX Mexico
- [X] NO Norway
- [X] NZ New Zealand
- [X] PL Poland
- [X] PT Portugal
- [X] RO Romania
- [X] RU Russian Federation
- [X] SD Sudan
- [X] SE Sweden
- [X] SG Singapore
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In addition to the designations made above, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except the designation(s) of ____________

The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)*

Sheet No. 3

Box No. VI PRIORITY CLAIM Further priority claims are indicated in the Supplemental Box ☐

The priority of the following earlier application(s) is hereby claimed:

Country *(in which, or for which, the application was filed)*	Filing Date *(day/month/year)*	Application No.	Office of filing *(only for regional or international application)*
item (1) Sweden	29 May 1996 29.05.1996	9602079-7	
item (2) Sweden	03 February 1997 03.02.1997	9700335-4	
item (3)			

Mark the following check-box if the certified copy of the earlier application is to be issued by the Office which for the purposes of the present international application is the receiving Office (a fee may be required):

[X] The receiving Office is hereby requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s) : ____________

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(If two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used)*: ISA / SE

Earlier search *Fill in where a search (international, international-type or other) by the International Searching Authority has already been carried out or requested and the Authority is now requested to base the international search, to the extent possible, on the results of that earlier search. Identify such search or request either by reference to the relevant application (or the translation thereof) or by reference to the search request:*

Country (or regional Office):	Date *(day/month/year)*:	Number:
(1) Sweden	29 May 1996	SE 96/00648

Box No. VIII CHECK LIST

This international application contains the following number of sheets:

1. request	: 3	sheets
2. description	: 21	sheets
3. claims	: 5	sheets
4. abstract	: 1	sheets
5. drawings	: 1	sheets
Total	: 31	sheets

This international application is accompanied by the item(s) marked below:

1. [ ] separate signed power of attorney
2. [X] copy of general power of attorney
3. [ ] statement explaining lack of signature
4. [X] priority document(s) *identified in Box No. VI as item(s):*
5. [ ] fee calculation sheet
6. [ ] separate indications concerning deposited microorganisms
7. [ ] nucleotide and/or amino acid sequence listing (diskette)
8. [X] other *(specify)*: copies of Official letter+ITS-Report

Figure No. 3 of the drawings (if any) should accompany the abstract when it is published.

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

Björn Dahlstrand

Stockholm, 27 May 1997

For receiving Office use only

1. Date of actual receipt of the purported international application:
2. Drawings: [ ] received: [ ] not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:
4. Date of timely receipt of the required corrections under PCT Article 11(2):
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6. [ ] Transmittal of search copy delayed until search fee is paid

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973210 5610

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H01F 27/34

A1

(11) International Publication Number: WO 97/45847

(43) International Publication Date: 4 December 1997 (04.12.97)

(21) International Application Number: PCT/SE97/00875

(22) International Filing Date: 27 May 1997 (27.05.97)

(30) Priority Data:

9602079-7	29 May 1996 (29.05.96)	SE
9700335-4	3 February 1997 (03.02.97)	SE

(71) Applicant *(for all designated States except US)*: ASEA BROWN BOVERI AB [SE/SE]; S-721 83 Västerås (SE).

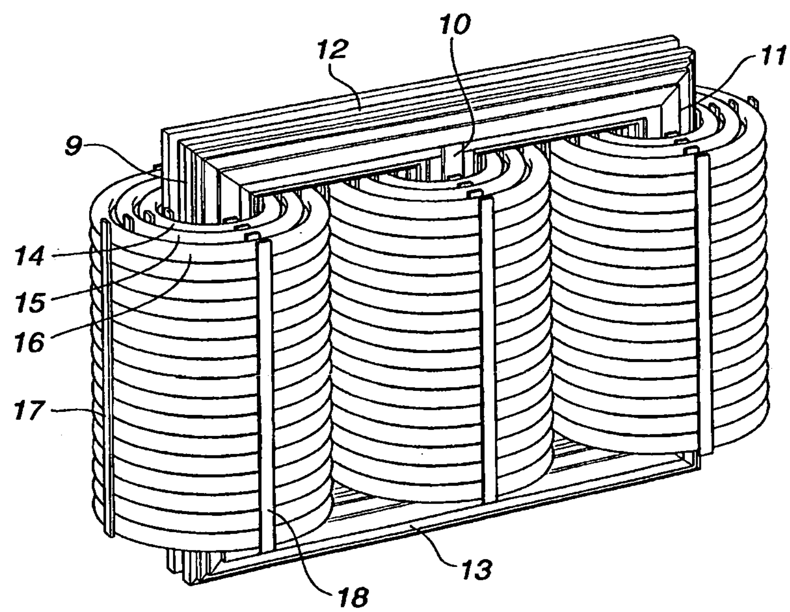
(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: LEIJON, Mats [SE/SE]; Hyvlargatan 5, S-723 35 Västerås (SE).

(74) Agents: DAHLSTRAND, Björn et al.; Asea Brown Boveri AB, Patent, Stockholm Office, S-120 86 Stockholm (SE).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, ES, FI, FI (Utility model), GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: TRANSFORMER/REACTOR



(57) Abstract

The present invention relates to a power transformer/reactor (14, 15, 16) for high voltages, comprising at least one winding having at least one current-carrying conductor. The winding comprises a solid insulation (7) surrounded by outer and inner layers (8, 6) serving for equalization of potential and having semiconducting properties. The layers (6, 8) and the insulation (7) adhere along essentially the whole of its contact surfaces. Said conductor is arranged interiorly of the inner semiconducting layer (6). The outer layer (8) is connected to ground or otherwise relatively low potential. Said solid insulation in the windings constitutes substantially the total electrical insulation in the power transformer/reactor.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
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Transformer, reactor

TECHNICAL FIELD

The present invention relates to a power transformer/reactor.

For all transmission and distribution of electric energy, transformers are used and their task is to allow exchange of electric energy between two or more electric systems. A transformer is a classical electrical product which has existed, both theoretically and practically, for more than 100 years. This is manifestly clear from the German patent specification DE 40414 from 1885. Transformers are available in all power ranges from the VA up to the 1000 MVA range. With respect to the voltage range, there is a spectrum up to the highest transmission voltages which are being used today.

A transformer belongs to an electrical product group which, regarding the fundamental mode of operation, is relatively easy to understand. For the energy transfer between the electric systems, electromagnetic induction is utilized. There are a great number of textbooks and articles which more or less theoretically and practically describe the theory, calculations, manufacture, use, service life, etc., of the transformer. In addition, there are a large number of patent documents relating to successively improved embodiments of the different parts of a transformer, such as, for example, windings, core, tank, accessories, cooling, etc.

The invention relates to a transformer belonging to the so-called power transformers with a rated power ranging from a few hundred kVA up to more than 1000 MVA with a rated voltage ranging from 3-4 kV and up to very high transmission voltages, 400 kV to 800 kV or higher.

The inventive concept which is the basis of the present invention is also applicable to reactors. The following

description of the background art, however, mainly relates to power transformers. As is well-known, reactors may be designed as single-phase and three-phase reactors. As regards insulation and cooling there are, in principle, the same embodiments as for transformers. Thus, air-insulated and oil-insulated, self-cooled, oil cooled, etc., reactors are available. Although reactors have one winding (per phase) and may be designed both with and without an iron core, the description of the background art is to a large extent relevant to reactors.

BACKGROUND ART, THE PROBLEMS

In order to place a power transformer/reactor according to the invention in its proper context and hence be able to describe a new approach in accordance with the invention in addition to the advantages afforded by the invention with respect to the prior art, a relatively complete description of a power transformer as it is currently designed will first be given below as well in addition to the limitations and problems which exist when it comes to calculations, design, insulation, earthing, manufacture, use, testing, transport, etc., of these transformers.

With respect to the above-mentioned, there is a comprehensive literature describing transformers in general, and more particularly, power transformers. Reference may be made, for example, to the following:

<u>The J & P Transformer Book, A Practical Technology of the Power Transformer</u>, by A. C. Franklin and D. P. Franklin, published by Butterworths, edition 11, 1990.

Regarding the internal electrical insulation of windings, etc., the following can be mentioned:

Transformerboard, Die Verwendung von Transformerboard in Grossleistungstransformatoren by H. P. Moser, published by H. Weidman AG, CH-8640 Rapperswil.

From a purely general point of view, the primary task of a power transformer is to allow exchange of electric energy between two or more electrical systems of, usually, different voltages with the same frequency.

A conventional power transformer comprises a transformer core, in the following referred to as a core, often of laminated oriented sheet, usually of silicon steel. The core comprises a number of core limbs, connected by yokes which together form one or more core windows. Transformers with such a core are often referred to as core transformers. Around the core limbs there are a number of windings which are normally referred to as primary, secondary and control windings. As far as power transformers are concerned, these windings are practically always concentrically arranged and distributed along the length of the core limbs. The core transformer usually has circular coils as well as a tapering core limb section in order to fill up the window as effectively as possible.

In addition to the core type transformer there is so-called shell-type transformer. These are often designed with rectangular coils and a rectangular core limb section.

Conventional power transformers, in the lower end of the above-mentioned power range, are sometimes designed with air cooling to dissipate the heat from inherent losses. For protection against contact, and for possibly reducing the external magnetic field of the transformer, it is often provided with an outer casing provided with ventilation openings.

Most of the conventional power transformers, however, are oil-cooled. One of the reasons for this is that the oil has an additional very important function as insulating medium. An oil-cooled and oil-insulated power transformer is therefore surrounded by an external tank on which, as will be clear from the description below, very high demands are placed.

Usually, means for water-cooling of the oil are provided.

The following part of the description will for the most part refer to oil-filled power transformers.

The windings of the transformer are formed from one or several coils connected in series built up of a number of turns connected in series. In addition, the coils are provided with a special device to allow switching between the taps of the coils. Such a device may be designed for tapping with the aid of screw joints or more often with the aid of a special switch which is operable in the vicinity of the tank. In the event that switching can take place for a transformer under voltage, the changeover switch is referred to as an on-load tap changer whereas otherwise it is referred to as a de-energized tap changer.

Regarding oil-cooled and oil-insulated power transformers in the upper power range, the contacts of the on-load tap changers are placed in special oil-filled containers with direct connection to the transformer tank. The contacts are operated purely mechanically via a motor-driven rotating shaft and are arranged so as to obtain a fast movement during the switching when the contact is open and a slower movement when the contact is to be closed. The on-load tap changers as such, however, are placed in the actual transformer tank. During the operation, arcing and sparking occur. This leads to degradation of the oil in the containers. To obtain less arcs and hence also less formation of soot and less wear on

the contacts, the on-load tap changers are usually connected to the high-voltage side of the transformer. This is due to the fact that the currents which need to be broken and connected, respectively, are smaller on the high-voltage side than if the on-load tap changers were to be connected to the low-voltage side. Failure statistics of conventional oil-filled power transformers show that it is often the on-load tap changers which give rise to faults.

In the lower power range of oil-cooled and oil-insulated power transformers, both the on-load tap changers and their contacts are placed inside the tank. This means that the above-mentioned problems with respect to degradation of the oil because of arcing during operation, etc., affect the whole oil system.

From the point of view of applied or induced voltage, it can broadly be said that a voltage which is stationary across a winding is distributed equally onto each turn of the winding, i.e., the turn voltage is equal on all the turns.

From the point of view of electric potential, however, the situation is completely different. One end of a winding is usually connected to earth. This means, however, that the electric potential of each turn increases linearly from practically zero in the turn which is nearest the earth potential up to a potential in the turns which are at the other end of the winding which correspond to the applied voltage.
This potential distribution determines the composition of the insulation system since it is necessary to have sufficient insulation both between adjacent turns of the winding and between each turn and earth.

The turns in an individual coil are normally brought together into a geometrical coherent unit, physically delimited from the other coils. The distance between the coils is also

determined by the dielectric stress which may be allowed to occur between the coils. This thus means that a certain given insulation distance is also required between the coils. According to the above, sufficient insulation distances are also required to the other electrically conducting objects which are within the electric field from the electric potential locally occurring in the coils.

It is thus clear from the above-mentioned description that for the individual coils, the voltage difference internally between physically adjacent conductor elements is relatively low whereas the voltage difference externally in relation to other metal objects - the other coils being included - may be relatively high. The voltage difference is determined by the voltage induced by magnetic induction as well as by the capacitively distributed voltages which may arise from a connected external electrical system on the external connections of the transformer. The voltage types which may enter externally comprise, in addition to operating voltage, lightning overvoltages and switching overvoltages.

In the current conductors of the coils, additional losses arise as a result of the magnetic leakage field around the conductor. To keep these losses as low as possible, especially for power transformers in the upper power range, the conductors are normally divided into a number of conductor elements, often referred to as strands, which are connected in parallel during operation. These strands must be transposed according to such a pattern that the induced voltage in each strand becomes as equal as possible and so that the difference in induced voltage between each pair of strands becomes as small as possible for internally circulating current components to be kept down at a reasonable level from the loss point of view.

When designing transformers according to the prior art, the general aim is to have as large a quantity of conductor

material as possible within a given area limited by the so-called transformer window, generally described as having as high a fill factor as possible. The available space shall comprise, in addition to the conductor material, also the insulating material associated with the coils, partly internally between the coils and partly to other metallic components including the magnetic core.

The insulation system, partly within a coil/winding and partly between coils/windings and other metal parts, is normally designed as a solid cellulose- or varnish-based insulation nearest the individual conductor element, and outside of this as solid cellulose and liquid, possibly also gaseous, insulation. In this way, windings with insulation and possible support parts represent large volumes which will be subjected to high electric field strengths which arise in and around the active electromagnetic parts of the transformer. In order to predetermine the dielectric stresses which arise and achieve a dimensioning with a minimum risk of breakdown, good knowledge of the properties of insulating materials is required. It is also important to achieve such a surrounding environment that it does not change or reduce the insulating properties.

The currently predominant insulation system for high-voltage power transformers comprises cellulose material as the solid insulation and transformer oil as the liquid insulation. The transformer oil is based on so-called mineral oil.

The transformer oil has a dual function since, in addition to the insulating function, it actively contributes to cooling of the core, the winding, etc., by removal of the loss heat of the transformer. Oil cooling requires an oil pump, an external cooling element, an expansion vessel, etc.

The electrical connection between the external connections of the transformer and the immediately connected coils/windings

is referred to as a bushing aiming at a conductive connection through the wall of the tank which, in the case of oil-filled power transformers, surrounds the actual transformer. The bushing is often a separate component fixed to the tank wall and is designed to withstand the insulation requirements being made, both on the outside and the inside of the tank, while at the same time it should withstand the current loads occurring and the resulting current forces.

It should be pointed out that the same requirements for the insulation system as described above regarding the windings also apply to the necessary internal connections between the coils, between bushings and coils, different types of switches and the bushings as such.

All the metallic components inside a power transformer are normally connected to a given earth potential with the exception of the current-carrying conductors. In this way, the risk of an unwanted, and difficult-to-control, potential increase as a result of capacitive voltage distribution between current leads at high potential and earth is avoided. Such an unwanted potential increase may give rise to partial discharges, so-called corona, which may be revealed during the normal acceptance tests, which partially are performed, compared with rated data, increased voltage and frequency. Corona may give rise to damage during operation.

The individual coils in a transformer must have such a mechanical dimensioning that they may withstand any stresses occurring as a consequence of currents arising and the resulting current forces during a short-circuit process. Normally, the coils are designed in such a way that the forces arising are absorbed within each individual coil, which in turn may mean that the coil cannot be dimensioned optimally for its normal function during normal operation.

Within a narrow voltage and power range of oil-filled power transformers, the windings are designed as so-called helical windings. This implies that the individual conductors mentioned above are replaced by thin sheets. Helical-wound power transformers are manufactured for voltages of up to 20-30 kV and powers of up to 20-30 MW.

The insulation system of power transformers within the upper power range requires, in addition to a relatively complicated design, also special manufacturing measures to utilize the properties of the insulation system in the best possible way. In order to obtain a good insulation to be obtained, the insulation system shall have a low moisture content, the solid part of the insulation shall be well impregnated with the surrounding oil and the risk of remaining "gas" pockets in the solid part must be minimal. To ensure this, a special drying and impregnating process is carried out on a complete core with windings before it is lowered into a tank. After this drying and impregnating process, the transformer is lowered into the tank which is then sealed. Before filling of oil, the tank with the immersed transformer must be emptied of all its air. This is done in connection with a special vacuum treatment. After carrying this out the tank is filled with oil.

In order to obtain the promised service life, etc., almost absolute vacuum is required during the vacuum treatment. This thus presupposes that the tank which surrounds the transformer is designed for full vacuum, which entails a considerable consumption of material and manufacturing time.

If electric discharges occur in an oil-filled power transformer, or if a local considerable increase of the temperature in any part of the transformer occurs, the oil disintegrates and gaseous products dissolve in the oil. The transformers are therefore usually provided with monitoring devices for detection of gas dissolved in the oil.

For weight reasons large power transformers are transported without oil. On-site installation of the transformer at the customer requires, in turn, renewed vacuum treatment. In addition, this is a process which, furthermore, has to be repeated each time the tank is opened for some repair work or inspection.

It is obvious that these processes are very time-consuming and cost-demanding and constitute a considerable part of the total time for manufacture and repair while at the same time requiring access to extensive resources.

The insulating material in conventional power transformers constitutes a large part of the total volume of the transformer. For a power transformer in the upper power range, oil quantities in the order of several tens of cubic metres of transformer oil are not unusual. The oil which exhibits a certain similarity to diesel oil is thinly fluid and exhibits a relatively low flash point. It is thus obvious that oil together with the cellulose constitutes a non-negligible fire hazard in the case of unintentional heating, for example at an internal flashover and a resulting oil spillage.

It is also obvious that, especially in oil-filled power transformers, there is a very large transport problem. Such a power transformer in the upper power range may have a total oil volume of several decades of cubic metres and may have a weight of up to several hundred tons. It is realized that the external design of the transformer must sometimes be adapted to the current transport profile, i.e., for any passage of bridges, tunnels, etc.

A short summary of the prior art with respect to oil-filled power transformers follows hereafter in which both its limitations and problem areas will be described:

An oil-filled conventional power transformer

- comprises an outer tank which is to house a transformer comprising a transformer core with coils, oil for insulation and cooling, mechanical support devices of various kinds, etc. Very large mechanical demands are placed on the tank, since, without oil but with a transformer, it shall be capable of being vacuum-treated to practically full vacuum. The tank requires very extensive manufacturing and testing processes and the large external dimensions of the tank also normally entail considerable transport problems;

- normally comprises a so-called pressure-oil cooling. This cooling method requires the provision of an oil pump, an external cooling element, an expansion vessel and an expansion coupling, etc.;

- comprises an electrical connection between the external connections of the transformer and the immediately connected coils/windings in the form of a bushing fixed to the tank wall. The bushing is designed to withstand any insulation requirements made, both regarding the outside and the inside of the tank;

- comprises coils/windings whose conductors are divided into a number of conductor elements, strands, which have to be transposed in such a way that the voltage induced in each strand becomes as equal as possible and such that the difference in induced voltage between each pair of strands becomes as small as possible;

- comprises an insulation system, partly within a coil/winding and partly between coils/windings and other metal parts which is designed as a solid cellulose- or varnish-based insulation nearest the individual conductor element and, outside of this, solid cellulose and a liquid, possibly also gaseous, insulation. In addition, it is

extremely important that the insulation system exhibits a very low moisture content;

- comprises as an integrated part an on-load tap changer, surrounded by oil and normally connected to the high-voltage winding of the transformer for voltage control;

- comprises oil which may entail a non-negligible fire hazard in connection with internal partial discharges, so-called corona, sparking in on-load tap changers and other fault conditions;

- comprises normally a monitoring device for monitoring gas dissolved in the oil, which occurs in case of electrical discharges therein or in case of local increases of the temperature;

- comprises oil which, in the event of damage or accident, may result in oil spillage leading to extensive environmental damage.

SUMMARY OF THE INVENTION, ADVANTAGES

The object of the invention is to offer a transformer concept within the power range which has been described under the description of the background art, that is, so-called power transformers with a rated power ranging from a few hundred kVA up to over 1000 MVA with a rated voltage ranging from 3-4 kV and up to very high transmission voltages, such as 400 kV to 800 kV or higher, and which does not entail the disadvantages, problems and limitations which are associated with the prior art oil-filled power transformers according to what is clear from the above-mentioned description of the prior art. The invention is based on the realization that, by designing

the winding or the windings in the transformer/reactor so that it comprises a solid insulation surrounded by an outer and an inner potential-equalizing semiconducting layer, within which inner layer the electric conductor is located, a possibility is provided of maintaining the electric field in the whole plant within the winding. The electric conductor must, according to the invention, be so arranged that it has such a conducting contact with the inner semiconducting layer that no harmful potential differences may arise in the boundary layer between the innermost part of the solid insulation and the surrounding inner semiconductor along the length of the conductor. A power transformer according to the invention exhibits obvious considerable advantages in relation to a conventional oil-filled power transformer. The advantages will be described in more detail below. As mentioned in the introductory part of the description, the invention also provides for the concept to be applied to reactors both with and without an iron core.

The essential difference between conventional oil-filled power transformers/reactors and a power transformer/reactor according to the invention is that the winding/windings thus comprise a solid insulation surrounded by an external and an internal potential layer as well as at least one electric conductor arranged inside the internal potential layer, designed as semiconductors. A definition of what is comprised by the concept semiconductor will be described below. According to a preferred embodiment, the winding/windings is/are designed in the form of a flexible cable.

At the high voltage levels which are required in a power transformer/reactor according to the invention, which is connected to high-voltage networks with very high operating voltages, the electric and thermal loads which may arise will impose extreme demands on the insulating material. It is known that so-called partial discharges, PD, generally constitute a serious problem for the insulating material in

high-voltage installations. If cavities, pores or the like arise at an insulating layer, internal corona discharge may arise at high electric voltages, whereby the insulating material is gradually degraded and which finally may lead to electric breakdown through the insulation. It is realized that this may lead to serious breakdown of, for example, a power transformer.

The invention is, inter alia, based on the realization that the semiconducting potential layers exhibit similar thermal properties as regards the coefficient of thermal expansion and that the layers are secured to the solid insulation. Preferably, the semiconducting layers according to the invention are integrated with the solid insulation to ensure that these layers and the adjoining insulation exhibit similar thermal properties to ensure good contact independently of the variations in temperature which arise in the line at different loads. At temperature gradients the insulating part with semiconducting layers will constitute a monolithic part and defects caused by different temperature expansion in the insulation and the surrounding layers do not arise. The electric load on the material is reduced as a consequence of the fact that the semiconducting parts around the insulation will constitute equipotential surfaces and that the electric field in the insulating part will hence be distributed nearly uniformly over the thickness of the insulation.

According to the invention, it must be ensured that the insulation is not broken down by the phenomena described above. This can be achieved by using as insulation layers, manufactured in such a way that the risk of cavities and pores is minimal, for example extruded layers of a suitable thermoplastic material, such as crosslinked PE (polyethylene), XLPE and EPR (ethylene-propylene rubber). The insulating material is thus a low-loss material with high

breakdown strength, which exhibits shrinkage when being loaded.

The electric load on the material is reduced as a consequence of the fact that the semiconducting parts around the insulation will constitute equipotential surfaces and that the electric field in the insulating part will hence be distributed nearly uniformly over the thickness of the insulation.

It is known, per se, in connection with transmission cables for high-voltage and for transmission of electric energy, to design conductors with an extruded insulation, based on the premise that the insulation should be free from defects. In these transmission cables, the potential lies, in principle, at the same level along the whole length of the cable, which provides a high electric stress in the insulating material. The transmission cable is provided with one inner and one outer semiconducting layer for potential equalization.

The present invention is thus based on the realization that, by designing the winding according to the characteristic features described in the claims as regards the solid insulation and the surrounding potential-equalizing layers, a transformer/reactor can be obtained in which the electric field is kept within the winding. Additional improvements may also be achieved by constructing the conductor from smaller insulated parts, so-called strands. By making these strands small and circular, the magnetic field across the strands will exhibit a constant geometry in relation to the field and the occurrence of eddy currents will be minimized.

According to the invention, the winding/windings is/are thus preferably made in the form of a cable comprising at least one conductor comprising a number of strands and with an inner semiconducting layer around the strands. Outside of this inner semiconducting layer is the main insulation of the cable in the form of a solid insulation, and around this

solid insulation is an outer semiconducting layer. The cable may in certain contexts have additional outer layers.

According to the invention, the outer semiconducting layer shall exhibit such electrical properties that a potential equalization along the conductor is ensured. The semconducting layer must not, however, exhibit such conductivity properties that the induced current causes an unwanted thermal load. Further, the conductor properties of the layer must be sufficient to ensure that an equipotential surface is obtained. The resistivity, ρ, of the semiconducting layer shall exhibit a minimum value, $\rho_{min} = 1\ \Omega cm$, and a maximum value, $\rho_{max} = 100\ k\Omega cm$, and, in addition, the resistance of the semiconducting layer per unit of length in the axial extent, R, of the cable shall exhibit a minimum value $R_{min} = 50\ \Omega/m$ and a maximum value $R_{max} = 50\ M\Omega/m$.

The inner semiconducting layer must exhibit sufficient electrical conductivity in order for it to function in a potential-equalizing manner and hence equalizing with respect to the electric field outside the inner layer. In this connection it is important that the layer has such properties that it equalizes any irregularities in the surface of the conductor and that it forms an equipotential surface with a high surface finish at the boundary layer with the solid insulation. The layer may, as such, be formed with a varying thickness but to ensure an even surface with respect to the conductor and the solid insulation, its thickness is suitably between 0.5 and 1 mm. However, the layer must not exhibit such a great conductivity that it contributes to induce voltages. For the inner semiconducting layer, thus, $\rho_{min} = 10^{-6}\ \Omega cm$, $R_{min} = 50\ \mu\Omega/m$ and, in a corresponding way, $\rho_{max} = 100\ k\Omega cm$, $R_{max} = 5\ M\Omega/m$.

Such a cable which is used according to the invention is an improvement of a thermoplastic cable and/or a cross linked thermoplastic such as XLPE or a cable with ethylene propylene

(EP) rubber insulation or other rubber, for example silicone. The improvement comprises, inter alia, a new design both as regards the strands of the conductors and in that the cable has no outer casing for mechanical protection of the cable.

A winding comprising such a cable will entail quite different conditions from the insulation point of view from those which apply to conventional transformers/reactor windings due to the electric field distribution. To utilize the advantages afforded by the use of the mentioned cable, there are other possible embodiments as regards earthing of a transformer/reactor according to the invention than what apply to conventional oil-filled power transformers.

It is essential and necessary for a winding in a power transformer/reactor according to the invention that at least one of the strands of the conductor is uninsulated and arranged such that good electrical contact is achieved with the inner semiconducting layer. The inner layer will thus always remain at the potential of the conductor. Alternatively, different strands may be alternately conducting with electrical contact with the inner semiconducting layer.

As far as the rest of the strands are concerned, all of them or some of them may be varnished and hence insulated.

According to the invention the terminations of the high-voltage and low-voltage windings can either be of joint type (when the connection is to a cable system) or of cable termination type (when the connection is to a switchgear or to an overhead transmission line). These parts also consist of solid insulation material, thus fulfilling the same PD demands as the whole insulation system.

According to the invention the transformer/reactor can either have external or internal cooling, external meaning gas or

liquid cooling on earth potential and internal meaning gas or liquid cooling inside the winding.

Manufacturing transformer or reactor windings of a cable according to the above, entails drastic differences as regards the electric field distribution between conventional power transformers/reactors and a power transformer/reactor according to the invention. The decisive advantage with a cable-formed winding according to the invention is that the electric field is enclosed in the winding and that there is thus no electric field outside the outer semiconducting layer. The electric field from the current-carrying conductor is present only in the solid main insulation. Both from the design point of view and the manufacturing point of view this has considerable advantages:

- the windings of the transformer may be formed without having to consider any electric field distribution and the transposition of strands, mentioned under the background art, is omitted;

- the core design of the transformer may be formed without having to consider any electric field distribution;

- no oil is needed for electrical insulation of the winding, i.e., the medium surrounding the winding may be air;

- no oil is needed for cooling of the winding. The cooling can be performed on ground potential and as cooling medium a gas or a liquid can be used;

- no special connections are required for electrical connection between the outer connections of the transformer and the immediately connected coils/windings, since the electrical connection, contrary to conventional plants, is integrated with the winding;

- traditional transformer/reactor bushings are not necessary. Instead, field conversion from radial to axial field outside the transformer/reactor can be realized similar as for a traditional cable termination;

- the manufacturing and testing technology which is needed for a power transformer according to the invention is considerably simpler than for a conventional power transformer/reactor since the impregnation, drying and vacuum treatments described under the description of the background art are not needed. This provides considerably shorter production times;

- by using the technique for insulation, according to the invention, considerable possibilities are provided for developing the magnetic circuit of the transformer, which was given according to the prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described with reference to the accompanying drawings, wherein

Figure 1 shows the electric field distribution around a winding of a conventional power transformer/reactor,

Figure 2 shows an embodiment of a winding in the form of a cable in power transformers/reactors according to the invention, and

Figure 3 shows an embodiment of a power transformer according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows a simplified and fundamental view of the electric field distribution around a winding of a conventional

power transformer/reactor, where 1 is a winding and 2 a core and 3 illustrates equipotential lines, i.e., lines where the electric field has the same magnitude. The lower part of the winding is assumed to be at earth potential.

The potential distribution determines the composition of the insulation system since it is necessary to have sufficient insulation both between adjacent turns of the winding and between each turn and earth. The figure thus shows that the upper part of the winding is subjected to the highest dielectric stress. The design and location of a winding relative to the core are in this way determined substantially by the electric field distribution in the core window.

Figure 2 shows an example of a cable which may be used in the windings which are included in power transformers/reactors according to the invention. Such a cable comprises at least one conductor 4 consisting of a number of strands 5 with an inner semiconducting layer 6 disposed around the strands. Outside of this inner semiconducting layer is the main insulation 7 of the cable in the form of a solid insulation, and surrounding this solid insulation is an outer semiconducting layer 8. As previously mentioned, the cable may be provided with other additional layers for special purposes, for example for preventing too high electric stresses on other regions of the transformer/reactor. From the point of view of geometrical dimension, the cables in question will have a conductor area which is between 30 and 3000 mm^2 and an outer cable diameter which is between 20 and 250 mm.

The windings of a power transformer/reactor manufactured from the cable described under the summary of the invention may be used both for single-phase, three-phase and polyphase transformers/reactors independently of how the core is shaped. One embodiment is shown in Figure 3 which shows a three-phase laminated core transformer. The core comprises, in conventional manner, three core limbs 9, 10 and 11 and the

retaining yokes 12 and 13. In the embodiment shown, both the core limbs and the yokes have a tapering cross section.

Concentrically around the core limbs, the windings formed with the cable are located. As is clear, the embodiment shown in Figure 3 has three concentric winding turns 14, 15 and 16. The innermost winding turn 14 may represent the primary winding and the other two winding turns 15 and 16 may represent secondary windings. In order not to overload the figure with too many details, the connections of the windings are not shown. Otherwise the figure shows that, in the embodiment shown, spacing bars 17 and 18 with several different functions are located at certain points around the windings. The spacing bars may be formed of insulating material intended to provide a certain space between the concentric winding turns for cooling, supporting, etc. They may also be formed of electrically conducting material in order to form part of the earthing system of the windings.

CLAIMS

1. A power transformer/reactor comprising at least one winding, **characterized** in that the winding/windings comprise one or more current-carrying conductor, that around each conductor (4) there is arranged a first layer (6) with semiconducting properties, that around the first layer there is arranged a solid insulating part (7), and that around the insulating part there is arranged a second layer (8) with semiconducting properties.

2. A power transformer/reactor according to claim 1, **characterized** in that the first layer (6) is at substantially the same potential as the conductor.

3. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that the second layer (8) is arranged in such a way that it essentially constitutes an equipotential surface surrounding the conductor/conductors.

4. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that the second layer (8) is connected to earth potential.

5. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that the semiconducting layers (6,8) and the insulating part (7) have substantially the same coefficient of thermal expansion such that, upon a thermal movement in the winding, defects, cracks or the like do not arise in the boundary layer between the semiconducting layers and the insulating part.

6. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that each of the semiconducting layer (6,8) is secured to the adjacent solid

insulating part (7) along essentially the whole adjoining surface.

7. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that the winding/windings is/are designed in the form of a flexible cable.

8. A power transformer/reactor according to claim 7, **characterized** in that the cable is manufactured with a conductor area which is between 30 and 3000 mm^2 and with an outer cable diameter which is between 20 and 250 mm.

9. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that the solid insulation (7) are formed by polymeric materials.

10. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that the first layer (6) and/or the second layer (8) are formed by polymeric materials.

11. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that the solid insulation (7) has been obtained by extrusion.

12. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that the current-carrying conductor (4) comprises a number of strands, said strands being insulated from each other except a few strands that are uninsulated in order to secure electric contact with the first semiconducting layer (6).

13. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that at least one of the strands of the conductor (4) is uninsulated and arranged

in such a way that electrical contact is achieved with the inner semiconducting layer.

14. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that the power transformer/reactor comprises a core consisting of magnetic material.

15. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that the power transformer/reactor comprises an iron core consisting of core limbs and yokes.

16. A power transformer/reactor according to claim 1-13, **characterized** in that the power transformer/reactor is formed without an iron core (air-wound).

17. A power transformer/reactor comprising at least two galvanically separated windings according to any preceding claim, **characterized** in that the windings are concentrically wound.

18. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that the power transformer/reactor is connected to two or more voltage levels.

19. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that the terminals of the high and/or low-voltage winding are jointed to a power cable and/or made similar to power cable termination(s).

20. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that substantially all of the electrical insulation in the transformer/reactor is enclosed between the conductor (4) the second layer (8) of

the windings and which insulation is in the form of solid insulation.

21. A power transformer/reactor according to one or more of the preceding claims, **characterized** in that the winding thereof is designed for high voltage, suitably in excess of 10 kV, in particular in excess of 36 kV, and preferably more than 72,5 kV and up to very high transmission voltages, such as 400 kV to 800 kV or higher.

22. A power transformer/reactor according to one or more of the preceding claims, **characterized** in the transformer/reactor is designed for a power range in excess of 0.5 MVA, preferably in excess of 30 MVA.

23. The cooling of a power transformer/reactor according to one or more of the preceding claims, **characterized** in that the power transformer/reactor is cooled with liquid and/or gas on earth potential.

24. A method for electric field control in a power transformer/reactor comprising a magnetic field generating circuit having at least one winding with at least one electrical conductor and an insulation present externally thereof, **characterized** in that the insulation is formed by a solid insulation material and that an outer layer is provided externally of the insulation, said outer layer being connected to ground or otherwise a relatively low potential and having an electrical conductivity being higher than the conductivity of the insulation but lower than the conductivity of the electrical conductor so as to function for equalization of potential and cause the electrical field to be substantially enclosed in the winding internally of the outer layer

25. A method in production of a power transformer/reactor according to one ore more of the preceding claims,

characterized in that a flexible cable is used as a winding and that the winding of the cable to form the winding/windings of the transformer/reactor is assembled on-site.

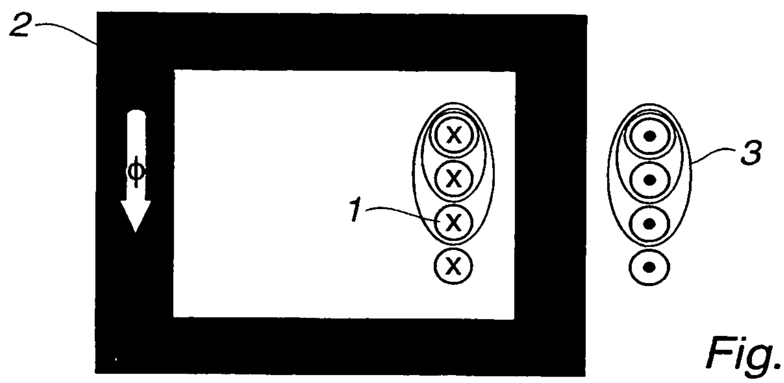

Fig. 1

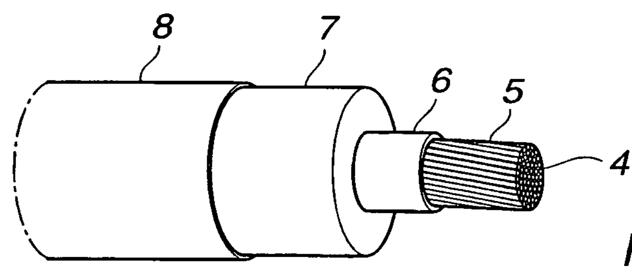

Fig. 2

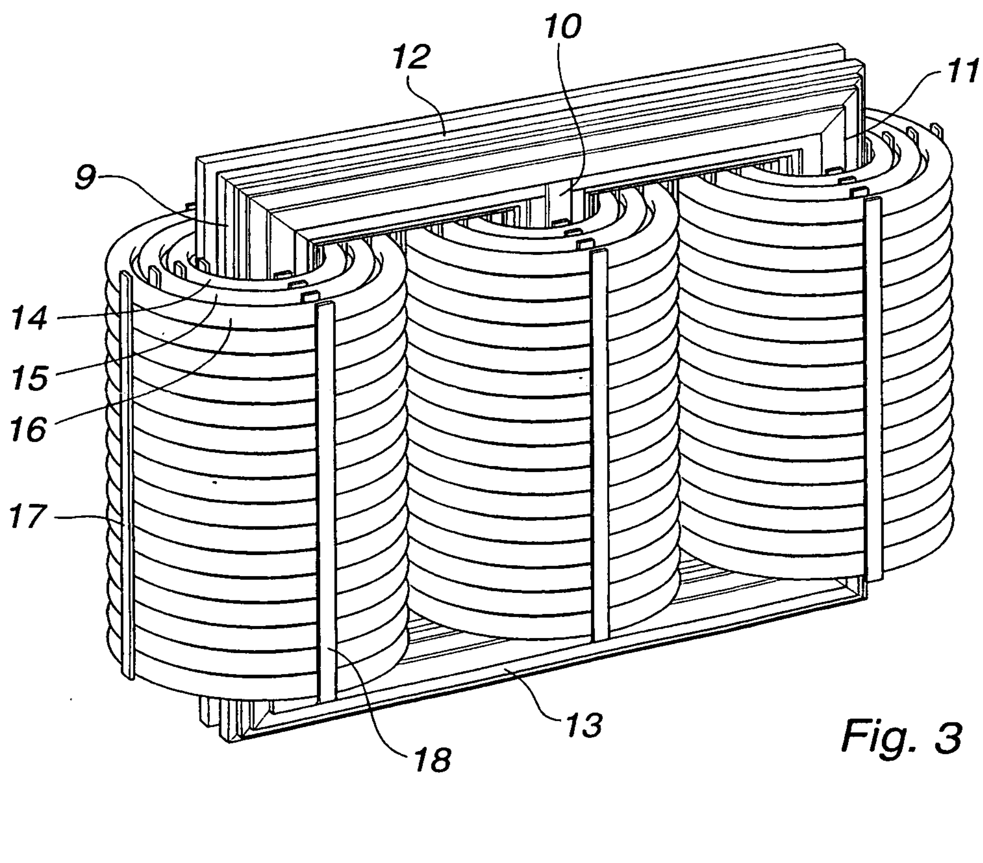

Fig. 3